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Vertical Foreign Direct Investment, Knowledge Spillovers and the Global Growth: A Q-theory Approach

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Abstract:

This paper combines several earlier contributions and studies the effects different FDI related knowledge spillovers (intra-industry spillovers, local learning-by-doing spillovers, and FDI spillovers through imitation) on the rate of multinationalization, investment level in R&D in the North and the global long-run capital growth rate. Tobin's Q method is applied and interesting results are shown — the higher rate of multinationalization is harmful to the long-run global knowledge capital growth, because of lower local learning-by-doing spillover effects in the North and a higher loss in capital due to the fixed cost premium for multinational corporations. In addition, a lower imitation rate, higher disadvantage cost, smaller wage gap between regions, or a smaller elasticity of substitution between varieties decrease the expected profits for MNCs, leading to a higher rate of multinationalization and a lower level of investment in innovation, which in turn reduces the long-run knowledge capital growth rate.

Key words: Foreign Direct Investment; Multinational corporations; Growth; Knowledge spillovers; Tobin's Q

JEL Classification: F0; O0

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1. Introduction

Formal economic theories modeling the impact of foreign direct investment (FDI) from developed to developing countries (a North-South FDI framework or a vertical FDI) on long-run growth through knowledge spillovers have only appeared in the past decade. The purpose of this vertical FDI is to exploit the lower wage rate in the host country. This is obviously profitable for multinational corporations (MNCs) themselves. However, is it good for the long-run growth of the host, the home, and the global economy? Most North-South FDI studies focus on the effect of knowledge spillovers on host countries. Findings of these models are mixed due to different assumptions and different setups of the models. However, the later parts of the question are almost neglected, since many vertical FDI models take the assumption that the amount of FDI and knowledge in the host country are so small that FDI have no effect on the home or the global economy.

The amount of FDI has increased dramatically during the past decade as developing countries gradually reduced their investment barriers. Therefore, the effects of vertical FDI on home and global economy should no longer be neglected. This research combines Grossman-Helpman (1991a), Baldwin-Braconier-Forslid (2001) and Lai (1998) into an endogenous vertical FDI and growth model to fill this gap. It contributes to the literature by studying the effects FDI-related knowledge spillovers on the rate of multinationalization, the investment level in R&D, and the global long-run (knowledge capital) growth rate.

Also, in contrast to empirical findings, almost all of the FDI and growth studies assume that knowledge is homogenously contributed to northern innovation regardless of its sectors and geographic locations.[1] Do different kinds of spillover from FDI function differently in affecting growth? And what if the knowledge capital stocks in developing countries are not small enough to be neglected? This study formally models these questions by separately examining intra-industry spillovers, local learning-by-doing spillovers, and FDI spillovers through imitation, and by allowing the reverse spillovers from host to home countries.

The model developed here predicts that a lower imitation rate in the host country leads to a higher rate of multinationalization and a lower level of R&D investment in the home country. As a result, global knowledge capital grows more slowly in the long run. This is because a lower level of imitation rate provides MNCs a longer period of monopoly power and profits. Therefore, a larger share of firms in the North wants to be MNCs. As more varieties are transferred from the North to the South, less local learning-by-doing spillovers are provided to northern innovators, so that innovation becomes less efficient. As a result, the same amount of investment leads to fewer new varieties and a lower global long-run growth rate. In addition, a lower imitation rate in the South leads to a lower level of investment in R&D, which further decreases the long-run capital accumulation rate.

This result suggests that, the higher rate of multinationalization, due to a lower imitation rate, from the North to the South is harmful to everybody regarding the growth of knowledge capital in the long run. This is consistent with the results in Helpman (1993) and Glass-Saggi (2002). Helpman (1993) shows that, if the imitation rate is low enough

[1] Jaffe, Trajtenberg and Henderson (1993), Sjoholm (1996), and Keller (2001) find that the scale of the spillover effects from knowledge transfer is geographically limited and the scope of technology diffusion is severely limited by distance. Many empirical studies find that the spillovers within the sector are also positive, such as Baldwin, Braconier and Forslid (1999).

with the presence of FDI, the rate of innovation decreases in the long run and the world loses, because the terms of trade gain in the North cannot eliminate the negative welfare effect of both the terms of trade loss in the South and the reallocation of manufacturing that results in higher prices being paid for a larger fraction of products. Glass-Saggi (2002) shows that a low imitation rate makes both MNCs and northern firms safer, generates resource wasting, and reduces both FDI and innovation.

Other important results of this research are that a higher disadvantage cost, smaller wage gap between regions, and smaller elasticity of substitution between varieties reduce the expected profits of MNCs. In turn, this leads to a lower rate of multinationalization and a higher level of investment, and thus a higher long-run growth rate.

The rest of the paper is arranged as follows. Section 2 surveys relevant recent studies. Section 3 develops a simple static model that does not consider knowledge capital accumulation or spillovers. Section 4 adds endogenous knowledge capital growth. Knowledge capital accumulation is carried out only in the North. Learning experiences from previous knowledge and local production processes are separately studied. I this version, the model is solved by using Tobin's Q approach, and spillovers from MNCs to the South are ignored. Section 5 introduces uncertain southern imitation (spillovers from MNCs to the South) into the model. The relationships between the rate of imitation, multinationalization, and global long-run knowledge capital growth are studied. Determinants of the rate of multinationalization are also examined. The last section concludes.

2. Literature review

Economic research on knowledge transfer and spillovers confirms that one of the main channels for knowledge transfer is the activities of MNCs. MNCs are results from two types of FDI: FDI between developed countries similar in levels of wage rate and technology advancement (symmetric FDI) and FDI from developed countries to developing countries, where developed countries have higher level of technology and developing countries have lower wage rates (asymmetric FDI). The effects of asymmetric FDI on host countries are most frequently studied and the findings are different due to different setups and assumptions. Helpman (1993) shows that if the imitation rate is low enough with the presence of FDI, the South suffers from a deterioration of the terms of trade and from the reallocation of manufacturing that results in higher prices being paid for a larger fraction of products. Lai (1998) finds that a lower rate of imitation encourages the North to increase the rate of multinationalization, which raises the growth rate of the South.

In addition, many economists consider that the amount of FDI is small compared to the size of the home economy. Thus, they assume that FDI has little effect on the home country, and most asymmetric FDI studies focus only on host countries (Lai (1998) and Grossman-Helpman (1991a)). Helpman (1993) overcomes this gap and shows that a low imitation rate decreases the rate of innovation in the long run and the world loses from resource wasting when reallocating it into a larger share of higher pricing products. Glass and Saggi (2002) use a product cycle model to examine this question. They show that a low imitation rate makes both MNCs and northern firms safer, generates resource wasting, and reduces both FDI and innovation.

Finally, early models of MNCs do not include knowledge spillovers (Grossman and Helpman (1991a) and Helpman (1993)), so that MNCs play no direct role in their models in determining the endogenous growth rate. Later models of MNCs fill this gap, but few distinguish different types of knowledge spillover. Lai (1998) is an example. For simplicity his model assumes that, regardless of location and type, knowledge has the same spillover effect. This is different from the empirical findings of Jaffe, Trajtenberg and Henderson (1993), Sjoholm (1996), and Keller (2001), find that the scale of the spillover effects from knowledge transfer is geographically limited and the scope of technology diffusion is severely limited by distance

A central issue for further analysis is how different channels of spillovers operate. Baldwin-Braconier-Forslid (2001) distinguishes the effect on innovation of intra-industry spillovers and local learning-by-doing effects. They apply Tobin's Q approach to solve the model. Their study is for symmetric FDI only, where long-run growth is driven by ceaseless knowledge innovation and knowledge spillovers directly affect the endogenous growth rate via innovation and resource reallocation. FDI is undertaken to reduce transportation costs. The main result is that the share of MNCs among all firms [2] is positively correlated with the long-run growth rate. The intuition is that for symmetric countries, FDI generates production in both regions. This provides more local learning-by-doing effects as the share of MNCs increases. Their empirical test on seven manufacturing industries in nine OECD-countries for the period 1979 to 1991 confirms that both the intra-industry effect and FDI spillovers are positively correlated with the growth rate of labor productivity.

[2] The share is defined as the ratio of number of MNCs to the number of all firms in each country. This ratio is not solvable so that it is assumed to be a parameter.

3. The Static Model

This section develops a static North-South model of MNCs. In this model, the incentives for FDI, instead of saving transportation costs as in a model of symmetric countries, is to exploit the lower wage in the South. Therefore, instead of producing in both regions, MNCs transfer all production to the South. Appendix 1 provides a full description of the derivations for the static model.

3.1 Consumers

Two final goods are produced: Y is the homogenous (e.g. agricultural) good and X is the manufacturing good with horizontally differentiated varieties.

Consumers have preferences over both goods and their utility function is:

$$U = \ln\left(C_X^{\phi} C_Y^{1-\phi}\right), \qquad (1)$$

where $C_X \equiv \left\{ \int_0^{n+m+s} [c_i]^{1-1/\varepsilon} di \right\}^{\frac{1}{1-1/\varepsilon}}$ is consumption of good X. It is a composite of all differentiated varieties of goods, where the elasticity of substitution between varieties is ε with ε>1 and c_i is the consumption of variety i. The letters n, m, and s represent the number of varieties that are produced by northern, multinational, and southern firms. Finally, C_Y is the consumption of the homogenous good Y.

The utility maximization problem yields a standard CES demand function for x-variety (see Appendix1.1):

$$c_j = \frac{p_j^{-\varepsilon}}{\int_0^{n+m+s} p_i^{1-\varepsilon} di} \cdot \phi \cdot E = s_j \cdot \frac{\phi \cdot E}{p_j}. \qquad (2)$$

The consumption share of variety j is $s_j \equiv p_j c_j / \phi E = \left(p_j / P_X\right)^{1-\varepsilon}$, where $P_X = \left(\int_0^{n+m+s} p_i^{1-\varepsilon} di\right)^{1/(1-\varepsilon)}$ is the price index for manufacturing good X.. The global expenditure is E, the price for variety j is p_j. Expression (3) shows that the variety with a higher price would have a smaller quantity in consumption and a smaller market share, because the elasticity of substitution (ε) is greater than one.

3.2 Production

Labor (L) and knowledge capital (K) are the inputs for production. Labor endowments are internationally immobile. The homogenous good Y is produced with labor only, while good X also requires knowledge capital. In the South, one unit of labor produces a unit of good Y. Labor in the South is the numeraire, and its wage is normalized to one. Northern workers are more skilled: it only takes 1/w units of labor to produce a unit of good Y, where w>1.

The varieties of good X are produced by monopolistically competitive firms. Each firm must acquire a unit of knowledge capital to produce.[3] There are three kinds of producers of differentiated varieties: northern firms, southern firms, and MNCs. Setting up a firm in a foreign country is more costly than doing so locally, because of language barriers, cultural differences, and the unfamiliarity of relevant regulations and markets. These costs are modeled as a fixed cost premium (Γ). Finally, regardless of the ownership and location of firms, all firms use one unit of local labor to produce one unit

[3] Knowledge capital described by Markusen (2001)is a one-time investment for each multinational firm who has multiple plants. This saves the fixed costs for each multinational firm comparing to domestic firm who has only one plant. In this research, each firm only has one plant, regardless of its type and location, so that knowledge capital works differently.

of X. The price that optimizing firms charge consumers is $p = w/\alpha$, where w is the marginal cost and $0 < \alpha = 1 - 1/\varepsilon < 1$.

3.3 FDI

The share of knowledge capital owned by MNCs is $S^M = K^M/(K^N + K^M)$, and the share owned by northern firms is $S^N = K^N/(K^N + K^M) = 1 - S^M$.[4] Also define $S^S = K^S/(K^N + K^M)$ as the knowledge available to the South compared to that available in the North. Superscripts indicate the owner of the knowledge.

For firms completing innovation in the North, the choice between being an MNC or a northern firm is based on the following equation with complementary slackness:

$$S^M(1 - S^M)\left[\frac{\pi^N}{F} - \frac{\pi^M}{F(1+\Gamma)}\right] = 0 \qquad (3)$$

The variable π is the operating profit and F is the cost for one unit of knowledge capital. From this, all firms are either MNCs or northern firms, or firms are indifferent between being either type. The first two corner solutions are ignored since they are not of interest in the model. The last case implies that S^M is strictly between zero and one and the last term on the left hand side of (3) is zero.

The solution of the model in Appendix1.2 and Appendix 1.3 determine the expressions for profits of firms and global expenditure. Given these results, a firm chooses to be an MNC instead of a national firm in the North when

$$\frac{\pi^M}{(1+\Gamma)F} \geq \frac{\pi^N}{F}. \qquad (4)$$

[4] The capital share of MNCs is similar to the "ω" in Lai (1998), measuring the rate of multinationalization. These shares are exogenous in the static model, as well the following growth model. However, adding FDI spillovers in the host country through imitation permits this rate to be endogenized.

$\Rightarrow\ 0 \le \Gamma \le w^{\varepsilon-1} - 1$.[5] (5)

This shows that FDI exists only when the northern wage (wage gap between two regions) or the elasticity of substitution between varieties are large enough. If $\Gamma < w^{\varepsilon-1} - 1$, all firms move their production to the South; while if $\Gamma > w^{\varepsilon-1} - 1$, all these firms stay in the North and produce there. These two corner solutions are excluded as stated before. The purpose of this research is to study the case where the condition $\Gamma = w^{\varepsilon-1} - 1$ holds. In this case, firms are indifferent in their locations and Appendix1.5 shows that it is impossible to determine a unique S^M. In that case, any $1 > S^M > 0$ satisfies the equilibrium conditions, so that S^M can be simply treated as a parameter.[6] A similar result appears in Baldwin-Braconier-Forslid (2001), in which horizontal FDI is studied in symmetric developed countries and the share of multinationals is also undetermined and treated as a parameter.

4. The Benchmark Endogenous Growth Model

Using Baldwin-Braconier-Forslid (1999), this section adds knowledge capital innovation to the static model. Calculations and derivations for this section appear in Appendix 2.

4.1 Consumers

The consumer's utility is:

$$U_s = \int_{t=s}^{\infty} e^{-\rho(t-s)} \ln\left(C_{Xt}^{\phi} C_{Yt}^{1-\phi}\right) dt \quad , \qquad (6)$$

[5] Calculation is in Appendix1.4

[6] Section 5 shows that adding FDI spillovers to the host country makes it possible to endogenize the rate of multinationalization.

where $C_X \equiv \left\{ \int_0^{n+m+s} [c_i]^{1-1/\varepsilon} di \right\}^{\frac{1}{1-1/\varepsilon}}$ and $\varepsilon > 1$. The parameter ρ>0 measures the rate of time preference. Utility maximization generates the same demand function as in section 3.1 and an Euler equation $\dot{E}/E = r - \rho$, where r is the rate of return to savings.

4.2 Knowledge Capital

The innovation sector in the North performs all R&D. Each unit of new knowledge capital is produced with a_I units of northern labor, where a_I measures the efficiency of innovation in the R&D sector. It is:

$$a_I = \frac{1}{(K^N + K^M) + \lambda K^S + \mu n} , \qquad (7)$$

where $1 \geq \lambda \geq 0$ and $\mu \geq 0$.

Two kinds of spillovers are considered. The first comes from the global knowledge pool. Northern innovators know knowledge held by the North. Their access to knowledge held by foreigners depends on "the intra-industry spillover effect" (λ). When λ is one, southern knowledge is fully known in both regions. When λ is zero, southern knowledge has no effect on innovations in the North. The knowledge capital taken to the South by MNCs (K^M) is originally produced in the North and always known by northern innovators. Therefore, knowledge held by MNCs contributes as much as that held by northern firms in the knowledge pool.

The second kind of spillover depends on "the local learning-by-doing effect" (μ) and is proportional to the number of firms in the North. The idea is that innovators in the North can observe the production processes of local firms and learn from them.

The world knowledge capital is:

$$K = K^N + K^M + K^S.$$

The fact that the production of each variety requires one unit of knowledge capital as the fixed cost for local firms and (1+Γ) units for MNCs implies

$K^N = n$, $K^S = s$, and $K^M = (1+\Gamma)m$.

The amount of new knowledge capital generated by investing L_I units of northern labor in innovation is given by:

$$\dot{K} = \frac{L_I}{a_I} = L_I\left[(K^N + K^M) + \lambda K_0^S + \mu n\right], \qquad (8)$$

The growth rate of capital held by the North is:[7]

$$g^N = \frac{\dot{K}}{K^N + K^M} = L_I[1 + \lambda S_0^S + \mu(1 - S^M)] = L_I A, \qquad (9)$$

where $A = 1 + \lambda S_0^S + \mu(1 - S^M)$. The worldwide capital growth rate is $g = \dot{K}/K = g^N/(1 + S_0^S)$.[8]

Equations (8) and (9) show that, if the intra-industry spillover effect (λ) is positive as assumed, the more is the initial knowledge capital held in the South (K_0^S) the more new knowledge capital would be generated in the North. That is, the higher is the initial knowledge capital ratio held by the South to that by the North (S_0^S) the faster northern knowledge capital would grow. The intuition is that higher intra-industry knowledge spillover provides northern innovators a better understanding of the southern knowledge,

[7] See Appendix2.1 for calculation.
[8] See Appendix2.2 for derivation.

which reduces the innovation cost of new knowledge capital. Furthermore, the higher is λ the bigger effect southern knowledge has on northern innovation.

For simplicity, capital in the South is assumed fixed at its endowed level. There is no imitation, learning, nor innovation of knowledge capital held by MNCs.[9] Therefore, as the knowledge capital held by the North increases overtime, S_0^S approaches zero. That is, the global capital growth rate approaches the growth rate of knowledge capital held by the North. Finally, the growth rate of knowledge capital held by the South is zero.

4.3 FDI

For firms completing innovation in the North, their choice between becoming an MNC or northern firm is based on the following equation:

$$S^M(1-S^M)\left[\frac{\Pi^N}{F}-\frac{\Pi^M}{F(1+\Gamma)}\right]=0, \qquad (10)$$

where $\Pi^i \equiv \int_{s=0}^{\infty} e^{-rs}\pi_s^i ds$ is the expected lifetime profits of firm i ($i=N,M$) and π^i is the instantaneous operating profits. These profits, derived in Appendix1.2, are

$$\pi^M=\pi^S=\frac{(1-\alpha)\phi\cdot E}{w^{1-\varepsilon}n+m+s}=\frac{(1-\alpha)\phi\cdot E}{(K^N+K^M)[w^{1-\varepsilon}(1-S^M)+S^M+S^S]}$$

$$\pi^N=\frac{(1-\alpha)\cdot w^{1-\varepsilon}\cdot\phi\cdot E}{w^{1-\varepsilon}n+m+s}=\frac{(1-\alpha)\cdot w^{1-\varepsilon}\cdot\phi\cdot E}{(K^N+K^M)[w^{1-\varepsilon}(1-S^M)+S^M+S^S]}$$

In these profit functions, everything is time invariant except for the global expenditure (E) and (K^N+K^M). However, calculation of equilibrium innovation in equation (9) shows

[9] The next section adds imitation into the model, where southern firms learn from knowledge held by MNCs. Further extension, where the South perform innovation but with a lower efficiency level instead of imitating, is completely a different research and would be done in a separate paper.

that ($K^N + K^M$) changes at the rate of $g^N = L_I A$. In order to know what π^i is and how it changes overtime, expenditure (E) with knowledge capital accumulation is solved in Appendix2.3 as

$$E = \frac{L^S + wL^N - wL_I}{1-\phi(1-\alpha)}. \qquad (11)$$

The amount of labor invested in producing new knowledge capital is L_I. It is the state variable, which implies that $\dot{L}_I = 0$ in steady state. Since labor endowments are fixed, equation (11) and the Euler equation imply that $\dot{E} = 0$ and $r = \rho$ in equilibrium. That is, the global nominal expenditure is time invariant. From the profit functions, profits decrease at the rate g^N. Therefore, since g^N is time invariant in equilibrium, the expected profits are $\Pi \equiv \int_{s=t}^{\infty} e^{-r(s-t)} \pi_s ds = \pi / (\rho + g^N)$ where $j = N, M$.

Equation (10) becomes

$$S^M (1 - S^M) \left[\frac{\pi^N}{(\rho + g^N)F} - \frac{\pi^M}{F(1+\Gamma)(\rho + g^N)} \right] = 0$$

Therefore, the choice to be a MNC instead of a northern firm implies that the expression (4) must be satisfied. This result is the same as in the static model where $0 \le \Gamma \le w^{\varepsilon-1} - 1$.

4.3 Equilibrium Growth Rate

The key implication of Tobin's Q approach is that "the equilibrium level of investment is characterized by the equality of the stock market value of a unit of capital and the cost of the capital"[10]. Tobin's Q implies $q \equiv V / F = 1$. In other words, in equilibrium, the ratio of the value of a firm (V) to its fixed cost (F) should equal one

The model implies that $q^N \equiv V^N / F = q^M \equiv V^M /(1+\Gamma)F = 1$ in equilibrium. The value of the firm at time t is $V_t \equiv \int_{s=t}^{\infty} e^{-r(s-t)} \pi_s^i ds = \pi /(\rho + g^N)$ ($i = N, M$). Using MNCs to illustrate the calculation, Appendix2.4 provides this solution for the amount of labor engaged in innovation in equilibrium:

$$L_I^* = \frac{(L^S + wL^N)(1-\alpha)\phi A - w[1-\phi(1-\alpha)]\rho[S^M + (1+\Gamma)S_0^S + (1+\Gamma)w^{1-\varepsilon}S^N]}{w[1-\phi(1-\alpha)]A[S^M + (1+\Gamma)S_0^S + (1+\Gamma)w^{1-\varepsilon}S^N] + w\phi A(1-\alpha)} \tag{12}$$

From this amount and equation (9), the equilibrium capital growth rate is

$$g^{N^*} = \frac{(L^S + wL^N)(1-\alpha)\phi[1+\mu(1-S^M)] - w[1-\phi(1-\alpha)]\rho}{w} \tag{13}$$

If some amount of northern labor is hired in the innovation sector, a positive amount of new knowledge capital is generated along the growth path. The growth rate of capital is positive in this case. On the other hand, if all workers in the North produce goods Y or X and no workers are allocated to the innovation sector, there is no new knowledge capital generated and the growth rate of knowledge capital is zero. This implies that the signs for (12) and (13) must both be non-negative. Since the denominators in both equations are positive, the numerators must also be positive. In addition, since S_0^S approaches zero in equilibrium, the whole world experiences the same capital growth rate in equilibrium: $g^{N^*} = g^*$.

[10] Baldwin-Braconier-Forslid (2001), "Multinationals, Endogenous Growth and Technological Spillovers: Theory and Evidence".

How does a change in the share of capital held by multinationals affect the capital growth rate? Consider that

$$\frac{\partial g^*}{\partial S^M} = \frac{(L^S + wL^N)(1-\alpha)(-\phi\mu)}{w} \leq 0 \qquad (14)$$

That is, a higher rate of multinationalization implies a lower long-run capital growth rate. This occurs because MNCs bring varieties to the South for production. This reduces the number of varieties produced in the North and reduces the possibilities of learning-by-doing in the North. Therefore, knowledge held by northern firms contributes more to innovation than that held by MNCs. This implies that higher rates of multinationalization reduces the long-run growth rate.

5. An Extended Growth Model

In this section, the benchmark model is combined with the model of Lai (1998).The idea is that southern workers learn from the local production of new varieties by MNCs. Calculations and derivations appear in Appendix 3.

5.1 Innovation and imitation of knowledge capital

To compete in their market, southern firms imitate some varieties after workers gain experience from working in the MNCs. Assume that the (Poisson arrival) rate of imitation is $j = \dot{s}/m$ ($1 \geq j \geq 0$). The rate j is the probability that any variety initially produced by MNCs is imitated by the South in the next instant. [11] Therefore, the number of copied varieties per time period by the South is $\dot{s} = jm$.

[11] Two important factors affect this rate: the ability of southern workers to learn from MNCs and the strength of intellectual property protection (IPP). The higher is the learning ability and the lower is the strength of IPP, the sooner knowledge will diffuse from MNCs to the South.

Simple calculations show that the efficiency of innovation, the new capital stock invented, and the capital growth rate in the North are the same as those described in the previous section. In addition, since the new knowledge only comes from northern innovation, and imitation by the South does not affect the knowledge capital pool, the growth rate for the whole world remains $g = \dot{K}/K = g^N /(1+S_0^S)$.

The imitation by southern firms ensures that the stock of knowledge capital in the South grows. This growth rate is

$$g^S = \frac{\dot{K}^S}{K^S} = \frac{\frac{j}{1+\Gamma}\dot{K}^M}{K_0^S + \frac{j}{1+\Gamma}K^M} \qquad (15)$$

Appendix3.1 shows that $\mathrm{g}^{\mathrm{S}} = g^N = g = L_I A$ in the steady state.

5.2 Production of X

As before, northern firms, those MNCs whose products have not been imitated by the South, and the original Southern firms engage in monopolistic competition for differentiated varieties. Prices are w/α for northern goods and $1/\alpha$ for varieties not yet imitated in the South. After a variety is copied, the multinational firm and southern firms producing the same variety are assumed to engage in limit pricing (Bertrand) competition. Therefore, the price index of X is:

$$P_X = \left[\left(\frac{1}{\alpha}\right)^{1-\varepsilon} s_0 + \left(\frac{1}{\alpha}\right)^{1-\varepsilon}(m - j\cdot m) + 1^{1-\varepsilon}\cdot j\cdot m + \left(\frac{w}{\alpha}\right)^{1-\varepsilon} n\right]^{\frac{1}{1-\varepsilon}} \qquad (16)$$

Because the elasticity of substitution (ε) is greater than one and α is between zero and one, the price index of X is smaller than before. That is, imitation reduces the price of copied varieties to production costs.

The instant profit function for northern firms is the same as in the previous section. However, profits for MNCs with copied varieties and southern firms become zero once the variety is imitated. Therefore, the expected profit for MNCs becomes:

$$\Pi^M = \int_{\tau=0}^{\infty}\left[\left(\int_{s=0}^{t}\pi^M e^{-rs}ds\right)\cdot prob(\tau = t)dt\right] \qquad (17)$$

The probability that a variety produced by MNCs has been copied at time t is $prob(\tau = t)$. Following Lai (1998), assume that the duration τ between the date of an MNC setting up its firm in the South and the date of imitation is a random variable with exponential distribution, having a Poisson arrival rate j, where $prob(\tau \le t) = f(t) = 1 - e^{-jt}$ and $prob(\tau = t) = f'(t) = je^{-jt}$.

The profit function for MNCs and southern firms producing the same variety is $\Pi^M = \int_{\tau=0}^{\infty}\left[\left(\int_{s=0}^{t}\pi^M e^{-rs}ds\right)\cdot je^{-jt}dt\right]$, with the same π^M as in the previous section.[12]

As before, the elements in the profit function are time invariant, with the exception of E and $(K^N + K^M)$. From (9), $(K^N + K^M)$ changes at the rate $g^N = L_I A$. Thus, $\dot{E}$ equals zero and $r = \rho$ in equilibrium.

[12] Derivation of the expression for expenditure are in Appendix3.2.

Profit functions show that profits fall at the rate of g^N. Since g^N is time invariant in equilibrium, the expected profits are $\Pi^N = \pi^N/(\rho + g^N)$ and $\Pi^M = \pi^M/(\rho + j + g^N)$.

Thus, the choice of being an N-type or M-type firm is based on:

$$S^M(1-S^M)\left[\frac{\pi^N}{(\rho+g)F} - \frac{\pi^M_{Mono}}{(\rho+g+j)F(1+\Gamma)}\right] = 0 \quad . \tag{18}$$

Therefore, to choose to be an MNC instead of a northern firm, the following inequality must hold:

$$\Gamma \le \frac{\rho+g}{\rho+g+j} w^{\varepsilon-1} - 1 \tag{19}$$

For the same reasons as before, the two corner solutions are excluded and strict equality must hold for the expression in equilibrium. Inequality (19) is the same as (5) when j is zero. In addition, g is:

$$g = \frac{j(\Gamma+1)}{w^{\varepsilon-1} - 1 - \Gamma} - \rho \tag{20}$$

The growth rate of knowledge capital (g) is positively corthe related with southern imitation rate (j). This result is consistent with Helpman (1993) and Glass-Saggi (2002), but opposite to Lai (1998). [13]

5.3 Long-Run Capital Growth with Imitation

<u>5.3.1 Knowledge capital growth rate</u>

The amount of labor used in R&D in equilibrium is solved in Appendix 3.3 from the q for multinational firms. The knowledge capital growth rate is[14]:

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[13] Detailed comparisons would be provided after the equilibrium is solved.

$$g^* = \frac{(L^S + wL^N)(1-\alpha)\phi\left[1+\mu(1-S^M)\right]}{w\left\{\left[w^{1-\varepsilon}(1+\Gamma)(1-S^M)+S^M - jS^M\right]\cdot\left[1-(1-\alpha)\phi\right]+\alpha^{1-\varepsilon}jS^M + (1-\alpha)\phi\right\}}$$
$$- \frac{(\rho+j)w\left\{\left[w^{1-\varepsilon}(1+\Gamma)(1-S^M)+S^M - jS^M\right]\cdot\left[1-(1-\alpha)\phi\right]+\alpha^{1-\varepsilon}jS^M\right\}}{w\left\{\left[w^{1-\varepsilon}(1+\Gamma)(1-S^M)+S^M - jS^M\right]\cdot\left[1-(1-\alpha)\phi\right]+\alpha^{1-\varepsilon}jS^M + (1-\alpha)\phi\right\}} \quad (21)$$

When j equals zero, (21) simplifies to (13). In addition, combining equations (20) and (21), the equilibrium capital share of MNCs, that is the rate of multinationalization, is solved and shows in Appendix3. The expression for this share and the long-run capital growth rate are complicated and their analytical solutions cannot be signed. Therefore, the determination of the share of multinationalization and R&D investment level, and their relationship with long-run growth rate are examined using numerical methods.

5.3.2 Imitation, MNCs share, investment and long-run growth rate

The interest of this research is in equilibrium with both MNCs and northern firms, and where the R&D investment and all growth rates are not all zeros. For the numerical analysis, the following parameter values are selected to obtain such an equilibrium: w=2, ε=1.4, ϕ=0.5, $L_S = L_N$ =1, ρ=1, Γ=0.1, and μ=0.5. Figure 1 shows the relationship between the imitation rate and the rate of multinationalization (share of MNCs) when parameters. Effects of changes in w, ε, Γ, and μ on the rate of multinationalization, the R&D investment, and the long-run knowledge capital growth rate are studied later in the paper. Changes in the scale of labor force (L_N or L_S) and time preference (ρ) only shift the graph to the right or left without affecting the shapes of the different relations.

Figure 1 shows that a higher imitation rate leads to a lower rate of multinationalization. The intuition is that a higher imitation rate increases the MNCs' risk of losing their monopolistic power on varieties. This reduces expected profits for

[14] See Appendix3.4 for calculations.

MNCs. Thus, at the margin, firms in the North prefer to remain there instead of becoming a MNC. Fewer new varieties are taken to the South while more are kept in the North. Through the learning-by-doing spillover, innovations are more prevalent because more varieties are kept in the North for production.

Figure 2 shows that a higher imitation rate raises the level of R&D investment in the North (to get more new varieties). The intuition is obvious: as the risk of losing monopolistic power increases for MNCs, more new varieties are needed to maintain the market share and profits, which requires a higher level of investment in R&D in the North. It is clear that only when the imitation rate is high enough, about 0.2 in this case, investment in R&D is positive and is positively correlated with the imitation rate.

Figure 3 shows that a higher imitation rate leads to a lower long-run knowledge capital growth rate. Both of the features in Figures 1 and 2 imply that the North gets more new varieties and that MNCs enjoy more monopolistic profits before their old varieties are copied. More importantly, as described in equation (9), both the raises in R&D investment and the decrease in the rate of multinationalization increase the long-run growth rate. Therefore, a higher imitation rate leads to a lower long-run knowledge capital growth rate. Figure 3 shows this relationship. It is clear that the line in figure 3 is steeper than that in Figure 2. This arises from the fact that, as the imitation rate increases, not only the R&D investment level increases as shown in Figure 2 but also the innovation becomes more efficient due to a higher learning-by-doing effect from local productions in the North as explained for Figure 1.

Figure 4, combing Figures 1 and 3, shows the negative relationship between the rate of multinationalization and the long-run growth rate.

The result that "a lower imitation rate in the South leads to a higher rate of production transfer from North to South" is the same as the result in Lai (1998). However, Lai (1998) also predicts that the lower imitation rate increases the long-run growth rate, which is opposite to the result of this model. This opposition exists because of different assumptions and setups between two models. There are mainly three differences.

First, all knowledge in Lai (1998) contributes the same to innovation regardless of its location. More specifically, he assumes that the cost of innovating one additional new variety equals the reciprocal of the number of present varieties. There is no difference between varieties produced in the North and those in the South. Therefore, a higher rate of multinationalization, resulted from a lower imitation rate, would only transfer more varieties/knowledge to the South, which results in a higher growth in the South. However, in this model, knowledge capital stocks contribute differently when they are used in production at different regions. Equation (7) explains it well: knowledge kept in the North for production contributes more than that taken to the South when the learning-by-doing spillover (μ) is positive, because watching production processes from local firms in the North provides innovators further knowledge which reduces the production cost for new knowledge capital. Therefore, as in equation (9), higher rate of multinationalization, resulted in a lower imitation rate, decreases the long-run growth rate if the local learning-by-doing effect (μ) is positive.

Second, the long-run growth in Lai (1998) is driven by exogenous labor expansion. Changes in the rate of multinationalization do not affect the level of investment in innovation in the North. However, long-run growth in this model is driven by ceaseless innovation. The level and efficiency of R&D investment are directly affected by the rate of multinationalization — a higher rate of multinationalization (due to a lower imitation rate) reduces both the level and efficiency of R&D investment, which decreases the long-run knowledge capital growth rate.

Third, there is no disadvantage cost for setting up a multinational firm in Lai (1998) as this model does. Thus, higher rates of multinationalization do not result in more lost in knowledge capital on the way from the North to the South in his model as it does here.

However, this result of the negative relationship between the rate of multinationalization and long-run growth rate is consistent with Helpman (1993) and Glass and Saggi (2002). Helpman (1993) uses the welfare analysis and shows that, if the imitation rate is low enough with the presence of FDI, the rate of innovation decreases in the long run and the world loses, because the terms of trade gain in the North cannot eliminate the negative welfare effect of both the terms of trade loss in the South and the reallocation of manufacturing that results in higher prices being paid for a larger fraction of products. Glass-Saggi (2002) uses a product cycle model to show that a low imitation rate makes both MNCs and northern firms safer, generates resource wasting, and disincentives both FDI and innovation.

Result 1 is summarized from Figures 1 to 4 and all above descriptions.

Result 1: A lower imitation rate leads to a higher rate of multinationalization and a lower level of investment in innovation. As a result, knowledge capital grows more slowly in the long run.

5.3.3 Disadvantage cost, MNCs share and long-run growth rate

Intuitively, if the disadvantage cost (Γ) were to rise, there would be fewer MNCs and the original equilibrium would be broken. To reach a new equilibrium, similar to the previous case, the economy simultaneously must increase the investment level and reduce the rate of multinationalization to get more new varieties, for each corresponding imitation rate. These two responses permit MNCs to earn higher profits from the monopolistic phase to make up the expected reduction in profit from the higher disadvantage cost.

Figure 5 shows the change in the rate of multinationalization for corresponding imitation levels as the disadvantage cost rises from 0.05 to 0.1 and to 0.2. Consistent with the intuition, for each corresponding imitation rate, a higher disadvantage cost leads to a lower rate of multinationalization. For example, when imitation rate is 0.2, the highest disadvantage cost (0.2) makes FDI disappear from the model, the modest disadvantage cost (0.1) makes about 25% of the firms in the North to be MNCs, while the lowest disadvantage cost (0.05) makes the share to be 70%.

Figure 6 shows the effects of change in disadvantage cost on the long-run knowledge growth rate. There are just two lines in the figure, lacking the case where Γ is 0.2. As shown in Figure 5, when imitation is exceeds 0.11, no firm would be MNC, which is the corner solution of the model and is excluded from further research. However, when imitation rate is below 0.1, this low imitation rate leads to a high rate of multinationalization and a low R&D investment level, as described in section 5.3.2. Therefore, when the disadvantage cost is high enough (over 0.2 in this case), the amount of new capital generated by R&D investment is smaller than the amount of capital loses on the way to the South and the knowledge capital cannot grow at a positive rate. As Γ drops to 0.1, less capital would lose on the way to the South. Therefore, when the imitation rate is high enough (over 0.2 in this case), which provides a high investment level and a low rate of multinationalization, the amount of capital newly generated from R&D would exceed that amount of capital loses on the way to the South and the long-run growth rate becomes positive. When the imitation rate increases to about 0.23, the rate of multinationalization approaches zero and the long-run growth rate reaches its highest level (0.16). Finally, as Γ becomes 0.05, only when the imitation rate reaches about 0.256 does the long-run growth rate become non-negative. When the imitation rate reaches 0.3, the rate of multinationalization approaches zero and the long-run growth rate gets its highest level (0.2).

To summarize the relationship between the disadvantage cost and the rate of multinationalization and long-run growth, result 2 is presented as the following.

Result 2: A larger disadvantage cost for MNCs leads to a lower rate of multinationalization and a higher level of investment in innovation. As a result, knowledge capital grows faster in the long run.

5.3.4 The wage gap and elasticity of substitution

Remember that the wage gap between regions is determined by the skill of workers when they produce in the homogeneous sector. Northern workers are more skilled and use only 1/w units of labor to produce one unit of good Y, while southern workers have to use 1 unit of labor to do it. Therefore, wage gap is determined by sector Y and is an important parameter like the elasticity of substitution.

Intuitively, for everything else the same except that the wage gap increases, the price index for sector X increases and consumption of all varieties decreases. At the same time, since the relative price of northern goods increases, the decrease in consumption of northern goods would be greater than that all other goods produced in the South. Therefore, the relative profit of MNCs increases and more X firms in the North would want to be MNCs. To reach a new steady state, the economy simultaneously must decrease the investment level and increase the rate of multinationalization to get less new varieties.

Figure 7 shows the change in the rate of multinationalization for corresponding imitation levels as the wage gap rises from 1.5 to 1.8 and to 2. The rightward shifts of lines in the figure are consistent with the intuition analyzed above. When the imitation rate is 0.16, the smallest wage gap (1.5) makes MNCs disappear from the model, the modest wage gap (1.8) makes about 20% of the firms in the North be MNCs, while the largest wage (2.0) makes about 70%. As wage gap increases with corresponding imitation rate, multinationalization rate increases and R&D investment rate decreases, as a result the long-run knowledge capital growth rate deceases. Figure 8 shows this result. It is worth notifying that three lines in Figure 8 has no portion overlapping each other for any specific imitation rate (j). Therefore, to see the result clearly, imagine there exists a vertical line at j=0.16. When wage gap is 1.5, the growth rate would be at its highest level (0.27); when wage gap increases to 1.8, the middle line in Figure 8 crosses the vertical line at g=0.07; when wage gap increases to 2, the growth rate drops to zero.

An increase in the elasticity of substitution between varieties decreases the price index of sector X. Thus, since consumers more easily shift from higher-priced goods to lower-priced ones, relative consumption of northern goods decreases. Therefore, relative expected profits for MNCs increases, so that the effect of an increase in ε on the rate of multinationalization and the long run growth rate would be the same as those in the case of an increasing wage gap. Thus, it makes sense that Figure 9 is similar to Figure 7 while Figure 10 is similar to Figure 8. The only difference is that when the elasticity of substitution is small enough, investment and growth rates become zero.

Result 3 is concluded as the following from the above explanations.

Result 3: Increases in the wage gap or elasticity of substitution between varieties increases the rate of multinationalization, decreases the investment level, and decreases the long-run growth rate.

5.4 Solving for long-run GDP growth rate

Nominal GDP depends on expenditures and investments. Since $\dot{E} = 0$ and $\dot{L}_I = 0$, nominal GDP would also be a constant in steady-state equilibrium. Therefore, the growth rate of *real GDP* is the important variable to analyze. Real GDP equals nominal GDP divided by the price index. Thus, the rate of change in real GDP equals the negative of the rate of change in the price index.

$$g_{GDP}{}^{*} = -\frac{\dot{P}}{P} = -\left[(1-\phi)\cdot\frac{\dot{P}_Y}{P_Y} + \phi\cdot\frac{\dot{P}_X}{P_X}\right] = -\phi\cdot\frac{\dot{P}_X}{P_X} \qquad (21)$$

While $\frac{\dot{P}_X}{P_X} == \frac{1}{1-\varepsilon} g^{*}$[15]

[15] See Appendix3.5 for steps.

Therefore,

$$g_{GDP}{}^{*} = \frac{\phi}{\varepsilon - 1} g^{*} \qquad (22)$$

Therefore, parameters have the same effect on the long-run economic growth rate as they do to the long-run knowledge capital growth rate: higher imitation rate, lower wage gap between regions, and lower elasticity of substitution between varieties simultaneously increase the rate of multinationalization and decrease the R&D investment level, which decrease the long-run economic growth rate. It is clear that lower rate of elasticity of substitution would increase the economic growth more than it does to the knowledge capital growth rate, since consuming more of the cheaper goods provide higher utility. Besides, higher consumption share in the X sector increases the economic growth rate.

5. Conclusions

This study combines the models of Grossman-Helpman (1991a), Lai (1998), and Baldwin-Braconier-Forslid (2001). It contributes to the literature by separately studying the effects of intra-industry spillovers, local learning-by-doing spillovers and FDI spillovers to the growth of the global economy. It also considers the effects of the wage gap, the fixed cost premium for MNCs, the elasticity of substitution, and the imitation rate on the rate of multinationalization, investment in R&D and the long-run capital growth rate. It provides further theoretical evidence of the relationship between the FDI and growth literature. It also explores a new way, Tobin's Q approach, to study the effects of vertical FDI on global growth through different knowledge spillovers in a with resource allocation constraints.

The model predicts that with or without spillovers from MNCs to the South, a higher share of knowledge capital held by MNCs unambiguously decreases the long-run capital growth rate. A lower imitation rate in the South leads to a higher rate of multinationalization and a lower investment level in the North, so that the long-run capital accumulation rate is lower, which is consistent with the findings in Helpman (1993) and Glass-Saggi (2002). In addition, a higher disadvantage cost, a smaller wage gap between the regions or a smaller elasticity of substitution between varieties leads to a lower rate of multinationalization, a higher investment level and a higher long-run growth rate. Finally, higher intra-industry spillovers increase the rate of multinationalization and decrease the investment level without affecting the long-run growth rate.

As Blomstrom and Kokko (1998) state, instead of pure imitation from MNCs, the South could protect its market share is by investing in new technology by themselves as the North does. Therefore, one of the possible and interesting extensions of this paper is to consider the case where the South also has innovation ability.

Appendix1 The Static Model

1.1 **Consumer's problem:**

Max: $U = \ln\left(C_X^{\phi} C_Y^{1-\phi}\right)$ (1) Where $C_X \equiv \left\{ \int_0^{n+m+s} \left[c_i\right]^{1-1/\varepsilon} di \right\}^{\frac{1}{1-1/\varepsilon}}$ (2)

s.t. $P_X C_X + C_Y = E$

$U = \ln(C_X^{\phi} C_Y^{1-\phi}) + \lambda\left[E - (P_X C_X + C_Y)\right]$

First order conditions are the following if only (1) is used:

① $\frac{\partial U}{\partial C_X} = 0 \quad \Rightarrow \quad \frac{\phi C_X^{\phi-1} C_Y^{1-\phi}}{C_X^{\phi} C_Y^{1-\phi}} = -\lambda P_X$

② $\frac{\partial U}{\partial C_Y} = 0 \quad \Rightarrow \quad \frac{(1-\phi) C_X^{\phi} C_Y^{-\phi}}{C_X^{\phi} C_Y^{1-\phi}} = -\lambda$

③ $\frac{\partial U}{\partial \lambda} = 0 \quad \Rightarrow \quad \mathrm{E} - (\mathrm{C_X P_X} + \mathrm{C_Y}) = 0$

Combine ① and ②: $\frac{(1-\phi) C_X^{\phi} C_Y^{-\phi}}{C_X^{\phi} C_Y^{1-\phi}} P_X = \frac{\phi C_X^{\phi-1} C_Y^{1-\phi}}{C_X^{\phi} C_Y^{1-\phi}} \quad \Rightarrow \quad (1-\phi) C_X P_X = \phi C_Y$

$$\Rightarrow \quad \phi(C_X P_X + C_Y) = C_X P$$

$$\Rightarrow \quad \phi \cdot E = C_X P$$

Plug in ③, get $(1 - \phi) \cdot E = C_Y$.

A constant fraction (ϕ) of the expenditure E is spent in X while (1-ϕ) of E is spent in Y.

When (2) is used, first order conditions provide further information:

④ $\frac{\partial U}{\partial c_a} = 0 \quad \Rightarrow \quad \frac{\phi C_X^{\phi-1} C_Y^{1-\phi}}{C_X^{\phi} C_Y^{1-\phi}} \cdot \frac{1}{1-\frac{1}{\varepsilon}} \cdot \left(\int_0^{n+m+s} c_i^{1-\frac{1}{\varepsilon}} di \right)^{\frac{1}{1-\frac{1}{\varepsilon}}} \cdot (1-\frac{1}{\varepsilon}) = -\lambda P_a$

⑤ $\frac{\partial U}{\partial c_b}=0 \quad \Rightarrow \quad \frac{\phi C_X^{\phi-1}C_Y^{1-\phi}}{C_X^{\phi}C_Y^{1-\phi}}\cdot\frac{1}{1-\frac{1}{\varepsilon}}\cdot\left(\int_0^{n+m+s} c_i^{1-\frac{1}{\varepsilon}}di\right)^{\frac{1}{1-\frac{1}{\varepsilon}}}\cdot(1-\frac{1}{\varepsilon})=-\lambda P_b$

Divide ④ by ⑤,

$$\frac{p_a}{p_b}=\left(\frac{c_a}{c_b}\right)^{-\frac{1}{\varepsilon}} \quad \Rightarrow \quad \mathrm{c_b}=c_a\cdot\left(\frac{p_a}{p_b}\right)^{\frac{1}{\varepsilon}}$$

All varieties of X can be represented in terms of c_a and the price ratio between this variety and a in similar forms. Plug them into $\phi\cdot E=\int_0^{n+m+s}(c_i p_i)di$ and the consumption for each variety can be solved as: $c_j=\phi\cdot E\cdot\left(p_j^{-\varepsilon}/\int_0^{n+m+s}p_i^{1-\varepsilon}di\right)$.

1.2 Profits for firms:

$\pi^M=\frac{(1-\alpha)c^M}{\alpha}=\pi^S$ and $\pi^N=\frac{(1-\alpha)\cdot c^N}{\alpha}$

From (4), sales can be expressed as:

$$c^M=\frac{\left(\frac{1}{\alpha}\right)^{-\varepsilon}}{\int_0^{n+m+s}p_i^{1-\varepsilon}di}\cdot\phi\cdot E=c^S \text{ and } c^N=\frac{\left(\frac{w}{\alpha}\right)^{-\varepsilon}}{\int_0^{n+m+s}p_i^{1-\varepsilon}di}\cdot\phi\cdot E\,.$$

Therefore, profits are

$$\pi^M=\left(\frac{1}{\alpha}-1\right)c^M=\frac{(1-\alpha)c^M}{\alpha}=\pi^S$$

$$\pi^N=\left(\frac{w}{\alpha}-w\right)c^N=\frac{(1-\alpha)\cdot c^N}{\alpha}$$

$$\pi^M = \pi^S = \frac{(1-\alpha)}{\alpha} \cdot \frac{\left(\frac{1}{\alpha}\right)^{-\varepsilon}}{\left(\frac{w}{\alpha}\right)^{1-\varepsilon} n + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} m + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} s} \cdot \phi \cdot E = \frac{(1-\alpha)\phi \cdot E}{w^{1-\varepsilon} n + m + s}$$

$$\pi^N = \left(\frac{w}{\alpha} - w\right) c^N = \frac{(1-\alpha) w^{1-\varepsilon} \phi \cdot E}{w^{1-\varepsilon} n + m + s}$$

Divide both numerator and denominator by ($K^N + K^M$),

$$\pi^M = \pi^S = \frac{(1-\alpha)\phi \cdot E}{(w^{1-\varepsilon} S^N + \frac{S^M}{1+\Gamma} + S_0^S) \cdot (K^N + K^M)}$$

$$\pi^N = \left(\frac{w}{\alpha} - w\right) c^N = \frac{(1-\alpha) w^{1-\varepsilon} \phi \cdot E}{(w^{1-\varepsilon} S^N + \frac{S^M}{1+\Gamma} + S_0^S) \cdot (K^N + K^M)}$$

1.3 Expenditure:

$$E = L^S + wL^N + \pi^N n + \pi^M m + \pi^S s$$

The first term in E (L^S) is the labor income in the South, since the wage is one for southern workers. The second term on numerator (wL^N) is the labor income in the North and the last three terms ($\pi^N n + \pi^M m + \pi^S s$) are the capital earnings.

From appendix 2,

$$E = L^S + wL^N + \frac{(1-\alpha) w^{1-\varepsilon} \phi \cdot E}{w^{1-\varepsilon} n + m + s} \cdot n + \frac{(1-\alpha)\phi \cdot E}{w^{1-\varepsilon} n + m + s} \cdot m + \frac{(1-\alpha)\phi \cdot E}{w^{1-\varepsilon} n + m + s} \cdot s$$

$$E = L^S + wL^N + (1-\alpha)\phi \cdot E$$

$$E = \frac{L^S + wL^N}{1 - \phi(1-\alpha)}$$

1.4 FDI or not?

$$\frac{\pi^M}{(1+\Gamma)F} \geq \frac{\pi^N}{F}$$

$$\frac{(1-\alpha)\phi \cdot E}{(w^{1-\varepsilon}n+m+s)(1+\Gamma)} \geq \frac{(1-\alpha)w^{1-\varepsilon}\phi \cdot E}{w^{1-\varepsilon}n+m+s}$$

$$\frac{1}{1+\Gamma} \geq w^{1-\varepsilon}$$

Since $\varepsilon > 1$ and both sides of the inequality are greater than zero, it becomes $1 \leq 1+\Gamma \leq w^{\varepsilon-1}$. That is, $0 \leq \Gamma \leq w^{\varepsilon-1} - 1$.

1.5 Can S^M be determined?

From appendix 1-4, consumer's problem, producer's problem, choice and FDI or not, and the expenditures are solved and value of S^M between zero and one, inclusively, satisfies the equilibrium conditions. However, market-clearing conditions usually provide the extra condition to determine S^M.

Knowledge capital market clearing: $K = n + (1+\Gamma) + m + s$

Labor market clearing: $L = C_Y^S + C_Y^N + n \cdot c_i^N + m \cdot c_i^M + s \cdot c_i^S$

In the static model, there is no innovation so that the whole labor force is used in production.

① The production of southern homogeneous good Y: 1 unit of labor $\Leftrightarrow$ 1 unit of Y in the South $\Rightarrow$ $C_Y^S = L_Y^S$

② The production of northern homogeneous good Y: 1/w unit of labor ⇔ 1 unit of Y in the North ⇒ $C_Y^N \cdot \frac{1}{w} = L_Y^N$

③ The production of northern varieties of X: 1 northern worker ⇔ 1 unit of X

$$\Rightarrow n \cdot c_i^N = n \cdot \frac{\left(\frac{w}{\alpha}\right)^{-\varepsilon} \phi \cdot E}{\left(\frac{w}{\alpha}\right)^{1-\varepsilon} n + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} m + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} s}$$

④ The production of multinational varieties of X: 1 southern worker ⇔ 1 unit of X

$$\Rightarrow m \cdot c_i^M = n \cdot \frac{\left(\frac{1}{\alpha}\right)^{-\varepsilon} \phi \cdot E}{\left(\frac{w}{\alpha}\right)^{1-\varepsilon} n + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} m + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} s}$$

⑤ The production of southern varieties of X: 1 southern worker ⇔ 1 unit of X

$$\Rightarrow s \cdot c_i^S = n \cdot \frac{\left(\frac{1}{\alpha}\right)^{-\varepsilon} \phi \cdot E}{\left(\frac{w}{\alpha}\right)^{1-\varepsilon} n + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} m + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} s}$$

Therefore,

$$L = C_Y^S + C_Y^N \cdot \frac{1}{w} + n \cdot \frac{\left(\frac{w}{\alpha}\right)^{-\varepsilon} \phi \cdot E}{\left(\frac{w}{\alpha}\right)^{1-\varepsilon} n + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} m + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} s} + m \cdot \frac{\left(\frac{1}{\alpha}\right)^{-\varepsilon} \phi \cdot E}{\left(\frac{w}{\alpha}\right)^{1-\varepsilon} n + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} m + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} s}$$
$$+ s \cdot \frac{\left(\frac{1}{\alpha}\right)^{-\varepsilon} \phi \cdot E}{\left(\frac{w}{\alpha}\right)^{1-\varepsilon} n + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} m + \left(\frac{1}{\alpha}\right)^{1-\varepsilon} s}$$

$$L = C_Y^S + C_Y^N \cdot \frac{1}{w} + n \cdot \frac{\alpha w^{-\varepsilon}\phi \cdot E}{w^{1-\varepsilon}n + m + s} + m \cdot \frac{\alpha\phi \cdot E}{w^{1-\varepsilon}n + m + s} + s \cdot \frac{\alpha\phi \cdot E}{w^{1-\varepsilon}n + m + s}$$

$$L^S = C_Y^S + m \cdot \frac{\alpha\phi \cdot E}{w^{1-\varepsilon}n + m + s} + s \cdot \frac{\alpha\phi \cdot E}{w^{1-\varepsilon}n + m + s}$$

$$L^N = C_Y^N \cdot \frac{1}{w} + n \cdot \frac{\alpha w^{-\varepsilon}\phi \cdot E}{w^{1-\varepsilon}n + m + s}$$

$$E = \frac{L^S + wL^N}{1 - \phi(1-\alpha)}$$

$$\Rightarrow L^S + wL^N = E \cdot [1 - \phi(1-\alpha)]$$

Plug in L^S and L^N into the left hand side:

$$L^S + wL^N = C_Y^S + m \cdot \frac{\alpha\phi \cdot E}{w^{1-\varepsilon}n + m + s} + s \cdot \frac{\alpha\phi \cdot E}{w^{1-\varepsilon}n + m + s} + w \cdot \left(C_Y^N \cdot \frac{1}{w} + n \cdot \frac{\alpha w^{-\varepsilon}\phi \cdot E}{w^{1-\varepsilon}n + m + s} \right)$$

$$= C_Y^S + C_Y^N + \frac{m \cdot \alpha\phi \cdot E + s \cdot \alpha\phi \cdot E + n \cdot \alpha w^{1-\varepsilon}\phi \cdot E}{w^{1-\varepsilon}n + m + s}$$

$$= C_Y^S + C_Y^N + \alpha\phi \cdot E$$

From appendix 1,

$$C_Y = E - C_X = E - \phi E$$

Therefore,

$$L^S + wL^N = E - \phi E + \alpha\phi E = E[1 - (1-\alpha)\phi]$$

This gives the same condition as the expenditure, which implies that the labor market clearing condition in this model does not provide further information to help determine S^M.

Conclusion: S^M cannot be determined in the model. Any value between zero and one, inclusive satisfies the equilibrium conditions.

Appendix2 The Benchmark Model

2.1 Growth rate of knowledge capital held by the North.

$$g^N = \frac{\dot{K}}{K^N + K^M} = \frac{L_I\left[(K^N + K^M) + \lambda K_0^S + \mu K^N\right]}{K^N + K^M}$$

$$\Rightarrow g^N = g^M = L_I(1 + \lambda S_0^S + \mu S^N) = L_I\left[1 + \lambda S_0^S + \mu(1 - S^M)\right]$$

2.2 Growth rate of world capital:

$$g = \frac{\dot{K}}{K} = \frac{L_I\left[(K^N + K^M) + \lambda K_0^S + \mu K^N\right]}{K^N + K^M + K_0^S}$$

Divide both numerator and denominator by ($K^N + K^M$):

$$\mathrm{g} = \frac{L_I[1 + \lambda S_0^S + \mu(1 - S^M)]}{1 + S_0^S} = \frac{g^N}{1 + S_0^S}$$

2.3 Expenditure in the growth model without spillovers

$$E = L^S + wL^N - wL_I + \pi^N n + \pi^M m + \pi^S s$$

Everything would be the same for E except for the investment term. Therefore, from appendix1: $E = \dfrac{L^S + wL^N - wL_I}{1 - \phi(1 - \alpha)}$

2.4 Solve for equilibrium investment in producing new knowledge capital.

$$q^M \equiv \frac{V^M}{(1 + \Gamma)F} = \frac{\dfrac{\pi^M}{\rho + g^N}}{(1 + \Gamma)F} = 1$$

From $F = wa_I$ and $a_I = \frac{L_I}{g^N} \cdot \frac{1}{K^N + K^M} = \frac{L_I}{L_I A(K^N + K^M)} = \frac{1}{A(K^N + K^M)}$,

$$\text{denominator} = \frac{(1+\Gamma)w}{A(K^N + K^M)}$$

From (14), $Numerator = \frac{(1-\alpha)\phi \cdot E}{(w^{1-\varepsilon} n + m + s)(\rho + g^N)}$

Plug in $g^N = L_I A$ and E, $Numerator = \frac{(1-\alpha)\phi \cdot \frac{L + wL - wL_I}{1-\phi(1-\alpha)}}{\rho + L_I A}$

$$\text{Numerator} = \frac{(L + wL - wL_I)(1-\alpha)\phi}{(\rho + L_I A)(s + m + w^{1-\varepsilon} n)\left[1-\phi(1-\alpha)\right]} \qquad (26)$$

Substitute (25) and (26) back into (24),

$$q^M = \frac{\frac{(L + wL - wL_I)(1-\alpha)\phi}{(\rho + L_I A)(s + m + w^{1-\varepsilon} n)\left[1-\phi(1-\alpha)\right]}}{\frac{(1+\Gamma)w}{A(K^N + K^M)}} = 1$$

$$q^M = \frac{(L + wL - wL_I)(1-\alpha)\phi A(K^N + K^M)}{(1+\Gamma)w(\rho + L_I A)(s + m + w^{1-\varepsilon} n)\left[1-\phi(1-\alpha)\right]} = 1$$

Divide both numerator and denominator by $(K^N + K^M)$,

$$q^M = \frac{(L + wL - wL_I)(1-\alpha)\phi A}{(1+\Gamma)w(\rho + L_I A)(\frac{S^M}{1+\Gamma} + S_0^S + w^{1-\varepsilon} S^N)\left[1-\phi(1-\alpha)\right]} = 1 \qquad (27)$$

$$L_I^* = \frac{(L + wL)(1-\alpha)\phi A - w\left[1-\phi(1-\alpha)\right]\rho\left[S^M + (1+\Gamma)S_0^S + (1+\Gamma)w^{1-\varepsilon} S^N\right]}{w\left[1-\phi(1-\alpha)\right]A\left[S^M + (1+\Gamma)S_0^S + (1+\Gamma)w^{1-\varepsilon} S^N\right] + w\phi A(1-\alpha)}$$

From $A = 1 + \lambda S_0^S + \mu(1 - S^M)$, $\Gamma = w^{\varepsilon - 1} - 1$, and S_0^S approaches zero in equilibrium,

$$L_I^* = \frac{(L + wL)(1-\alpha)\phi\left[1 + \mu(1 - S^M)\right] - w\left[1-\phi(1-\alpha)\right]\rho}{w\left[1 + \mu(1 - S^M)\right]} \qquad (28)$$

Appendix3 Math calculation and derivation for the imitation model

3.1 Growth rate of southern knowledge capital.

$$g^S = \frac{\dot{K}^S}{K^S} = \frac{\frac{j}{1+\Gamma}\dot{K}^M}{K_0^S + \frac{j}{1+\Gamma}K^M}$$

Divide both numerator and denominator by ($K^N + K^M$).

$$g^S = \frac{\frac{j}{1+\Gamma}\cdot\frac{\dot{K}^M}{K^N + K^M}}{S_0^S + \frac{j}{1+\Gamma}\cdot\frac{K^M}{K^N + K^M}}$$

Since S_0^S approaches zero in equilibrium, it becomes: $g^S = \frac{\dot{K}^M}{K^M}$

The capital share of MNCs (S^M) is time invariant in equilibrium, therefore,

$$\frac{\dot{K}^M}{K^M} = \frac{\dot{K}^N}{K^N} = \frac{\dot{K}}{K^N + K^M} = g^N$$

3.2 Expenditure with imitation:

$$E = L^S + wL^N - wL_I + \pi^N n + \pi^M_{Mono}(m - jm) + \pi^S_0 s_0$$

$$E = L^S + wL^N - wL_I + \frac{(1-\alpha)w^{1-\varepsilon}\phi\cdot E}{w^{1-\varepsilon}n + m - jm + \alpha^{1-\varepsilon}\cdot jm + s_0}\cdot n + \frac{(1-\alpha)\phi\cdot E}{w^{1-\varepsilon}n + m - jm + \alpha^{1-\varepsilon}\cdot jm + s_0}\cdot(m - jm + s_0)$$

$$E = \frac{(L^S + wL^N - wL_I)\cdot\left(w^{1-\varepsilon}n + m - jm + s_0 + \alpha^{1-\varepsilon}jm\right)}{(w^{1-\varepsilon}n + m - jm + s_0)\cdot\left[1-(1-\alpha)\phi\right] + \alpha^{1-\varepsilon}jm}$$

Divide both numerator and denominator by ($K^N + K^M$),

$$E=\frac{(L^S+wL^N-wL_I)\cdot\left(w^{1-\varepsilon}S^N+\frac{S^M}{1+\Gamma}-j\cdot\frac{S^M}{1+\Gamma}+S_0^S+\alpha^{1-\varepsilon}j\cdot\frac{S^M}{1+\Gamma}\right)}{(w^{1-\varepsilon}S^N+\frac{S^M}{1+\Gamma}-j\cdot\frac{S^M}{1+\Gamma}+S_0^S)\cdot\left[1-(1-\alpha)\phi\right]+\alpha^{1-\varepsilon}j\cdot\frac{S^M}{1+\Gamma}} \qquad (39)$$

3.3 Solve for equilibrium investment level in R&D with imitation:

$$q^M\equiv\frac{V^M}{(1+\Gamma)F}=\frac{\frac{\pi_0^M}{\rho+j+g}}{(1+\Gamma)F}=1$$

Same as before,

$$\text{Denominator}=\frac{(1+\Gamma)w}{A(K^N+K^M)} \qquad (45)$$

From (38), numerator of (44) is

$$Numerator=\frac{(1-\alpha)\phi\cdot E}{(w^{1-\varepsilon}n+m-jm+\alpha^{1-\varepsilon}\cdot jm+s_0)\cdot(\rho+j+g)}$$

Plug in $g=L_IA$ and E,

$$Numerator=\frac{(1-\alpha)\phi\cdot\frac{(L^S+wL^N-wL_I)\cdot\left(w^{1-\varepsilon}n+m-jm+s_0+\alpha^{1-\varepsilon}jm\right)}{(w^{1-\varepsilon}n+m-jm+s_0)\cdot\left[1-(1-\alpha)\phi\right]+\alpha^{1-\varepsilon}jm}}{(\rho+L_IA+j)(w^{1-\varepsilon}n+m-jm+s_0+\alpha^{1-\varepsilon}jm)}$$

$$\text{Numerator}=\frac{(L^S+wL^N-wL_I)(1-\alpha)\phi}{(\rho+L_IA+j)\left\{(w^{1-\varepsilon}n+m-jm+s_0)\cdot\left[1-(1-\alpha)\phi\right]+\alpha^{1-\varepsilon}jm\right\}} \qquad (46)$$

Substitute (45) and (46) back into (44) and divide both numerator and denominator by (K^N+K^M),

$$(L^S+wL^N-wL_I)(1-\alpha)\phi A=$$
$$(\rho+L_IA+j)w\left\{\left[w^{1-\varepsilon}(1+\Gamma)S^N+S^M-jS^M+(1+\Gamma)S_0^S\right]\cdot\left[1-(1-\alpha)\phi\right]+\alpha^{1-\varepsilon}jS^M\right\}$$

Therefore, equilibrium investment level (L_I) is:

$$L_I^* =$$
$$\frac{(L^S + wL^N)(1-\alpha)\phi\left[1+\mu(1-S^M)\right] - (\rho + j)w\left\{\left[w^{1-\varepsilon}(1+\Gamma)(1-S^M) + S^M - jS^M\right]\cdot\left[1-(1-\alpha)\phi\right] + \alpha^{1-\varepsilon} jS^M\right\}}{w\left[1+\mu(1-S^M)\right]\left\{\left[w^{1-\varepsilon}(1+\Gamma)(1-S^M) + S^M - jS^M\right]\cdot\left[1-(1-\alpha)\phi\right] + \alpha^{1-\varepsilon} jS^M + (1-\alpha)\phi\right\}}$$

3.4 Solution of share of MNCs (from Mathematica)

$$\begin{aligned} S^{M*} &= \alpha^{\varepsilon}\cdot\left[jw(1+\Gamma) + w\rho\phi(1-\alpha)(1-w^{\varepsilon-1}+\Gamma) + (wL_N + L_S)\phi(1-\alpha)(1+\mu)(1-w^{\varepsilon-1}+\Gamma)\right]\cdot \\ &\quad [-j^2 w^{\varepsilon}\alpha + jw\alpha^{\varepsilon}(1+\Gamma - w^{\varepsilon-1} + jw^{\varepsilon-1}) - jw\alpha\phi(j - w^{\varepsilon-1} + jw^{\varepsilon-1} - \alpha) - jw^{\varepsilon}\alpha^{1+\varepsilon}\phi(1-j) \\ &\quad - jw\alpha^{\varepsilon}\Gamma\phi(1-\alpha) + (wL_N + L_S)w\alpha^{\varepsilon}\mu\phi(1-\alpha)(1+\Gamma - w^{\varepsilon-1})]^{-1} \end{aligned}$$

3.5 Solve for growth rate of price index in sector X.

From equation (35), the price index in sector X becomes:

$$P_X = \left[\left(\frac{1}{\alpha}\right)^{1-\varepsilon} s_0 + \left(\frac{1}{\alpha}\right)^{1-\varepsilon}(m - jm) + jm + \left(\frac{w}{\alpha}\right)^{1-\varepsilon} n\right]^{\frac{1}{1-\varepsilon}}$$
$$= \frac{1}{\alpha(1+\Gamma)^{\frac{1}{1-\varepsilon}}}\left[(1+\Gamma)K_0^S + K^M(1-j) + \alpha^{1-\varepsilon} jK^M + (1+\Gamma)w^{1-\varepsilon}K^N)\right]^{\frac{1}{1-\varepsilon}}$$

The change rate of the price index is:

$$\frac{\dot{P}_X}{P_X} = \frac{\frac{1}{1-\varepsilon}\left[\dot{K}^M(1-j) + \alpha^{1-\varepsilon} j\dot{K}^M + \dot{K}^N w^{1-\varepsilon}(1+\Gamma)\right]}{\left[(1+\Gamma)K_0^S + K^M(1-j) + \alpha^{1-\varepsilon} jK^M + (1+\Gamma)w^{1-\varepsilon}K^N\right]}$$

$$\frac{\dot{P}_X}{P_X} = \frac{\frac{1}{1-\varepsilon} g^*\left[K^M(1-j) + \alpha^{1-\varepsilon} jK^M + K^N w^{1-\varepsilon}(1+\Gamma)\right]}{\left[(1+\Gamma)K_0^S + K^M(1-j) + \alpha^{1-\varepsilon} jK^M + (1+\Gamma)w^{1-\varepsilon}K^N\right]}$$

Divide both numerator and denominator by $(K^N + K^M)$ and since S_0^S approaches zero in equilibrium,

$$\frac{\dot{P}_X}{P_X} == \frac{1}{1-\varepsilon} g^*$$

Since the price for Y is one, which is the numeraire, the change in price index of it is zero.

Therefore, the price index for the whole economy is:

$$g_{GDP}^{\ *} = -\left[(1-\phi)\cdot\frac{\dot{P}_Y}{P_Y} + \phi\cdot\frac{\dot{P}_X}{P_X}\right] = -\phi\cdot\frac{\dot{P}_X}{P_X} = \frac{\phi}{\varepsilon-1}g^{*} \qquad (49)$$

Appendix 4 Figures

Figure 1 The relationship between the strength of IPP and the rate of multinationalization

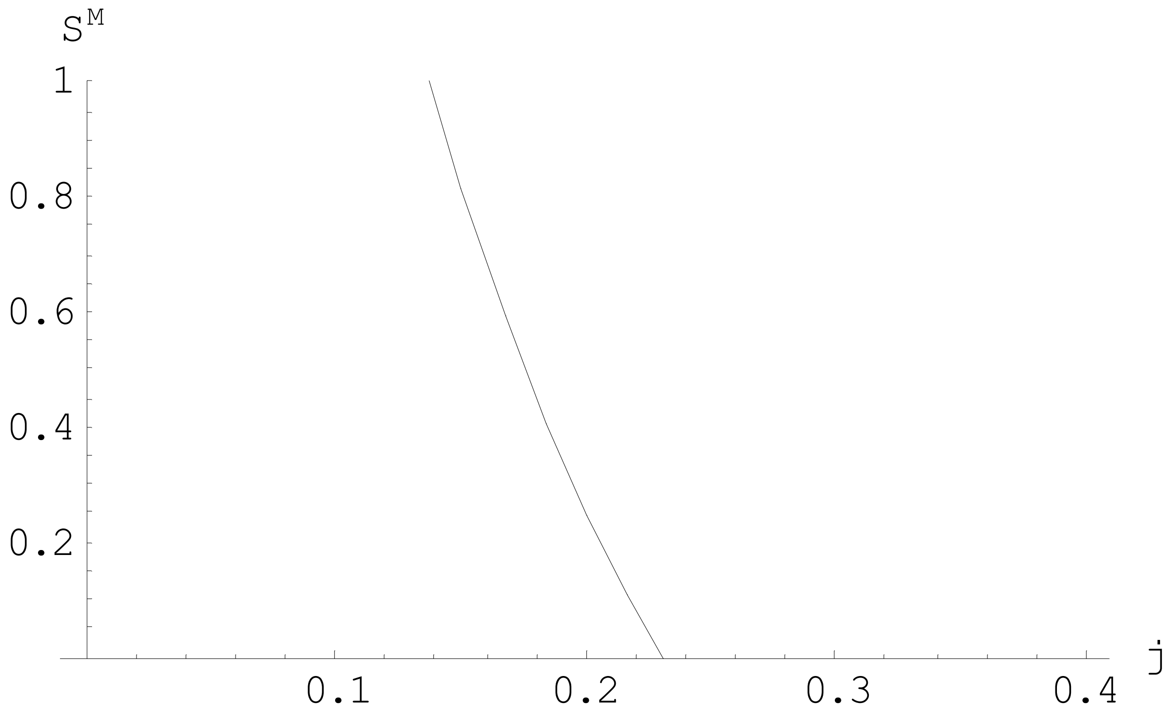


Figure 2 The relationship between the imitation rate and R&D investment

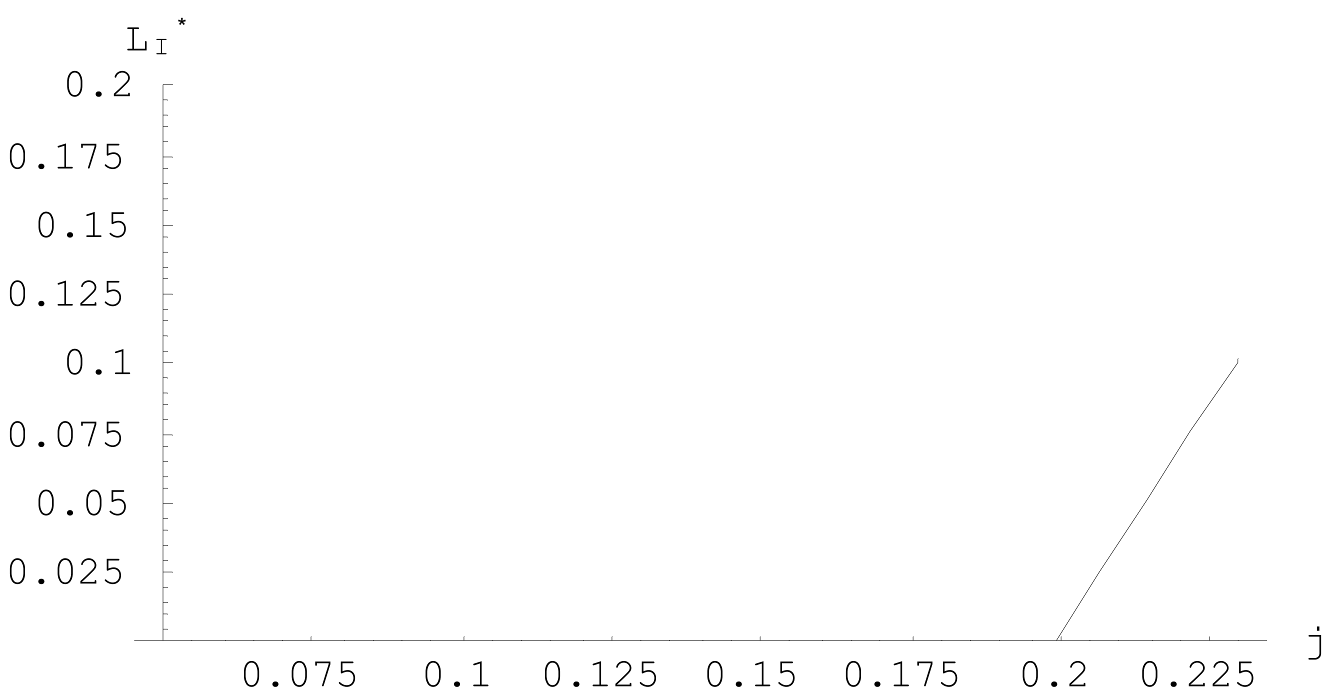


Figure 3 The relationship between rate of imitation and long-run capital growth

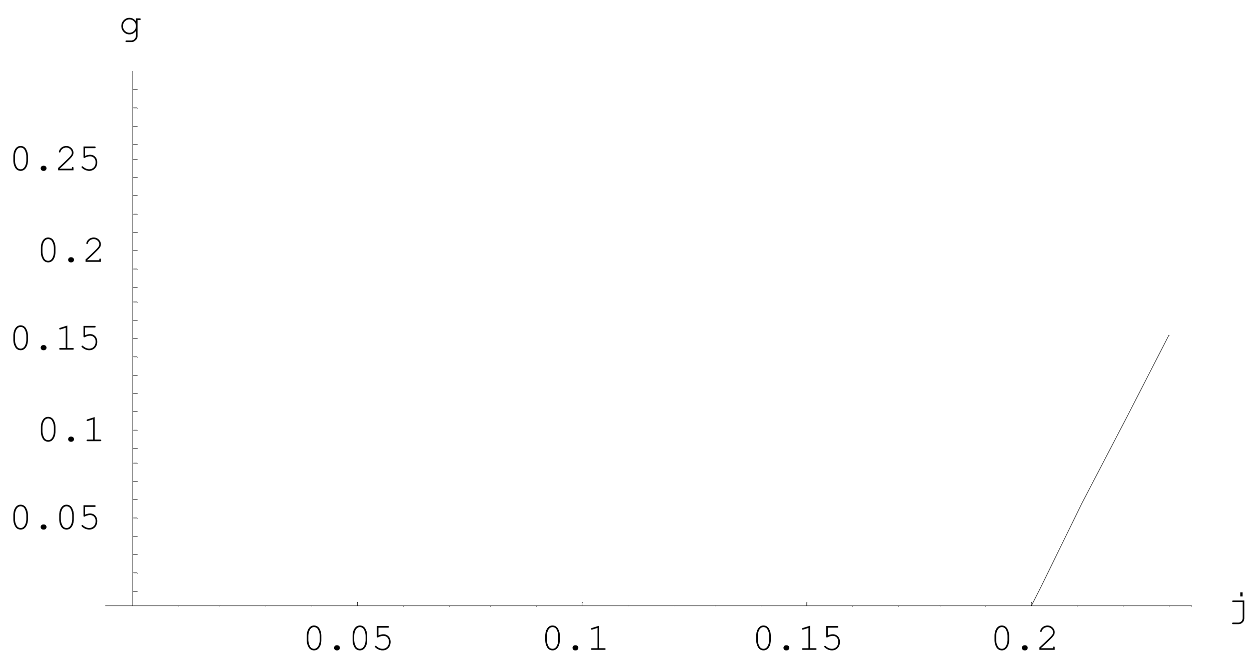


Figure 4 Relationship between the rate of multinationalization and growth

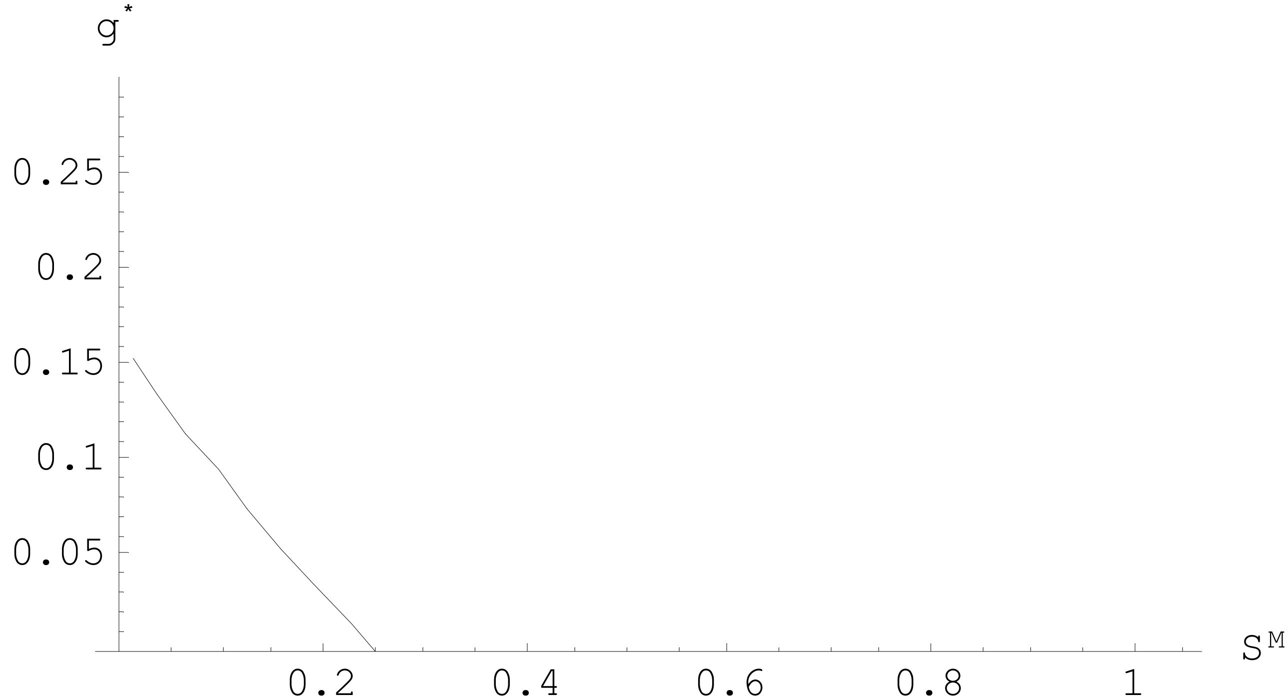


Figure 5 Effects of change in disadvantage costs on rate of multinationalization

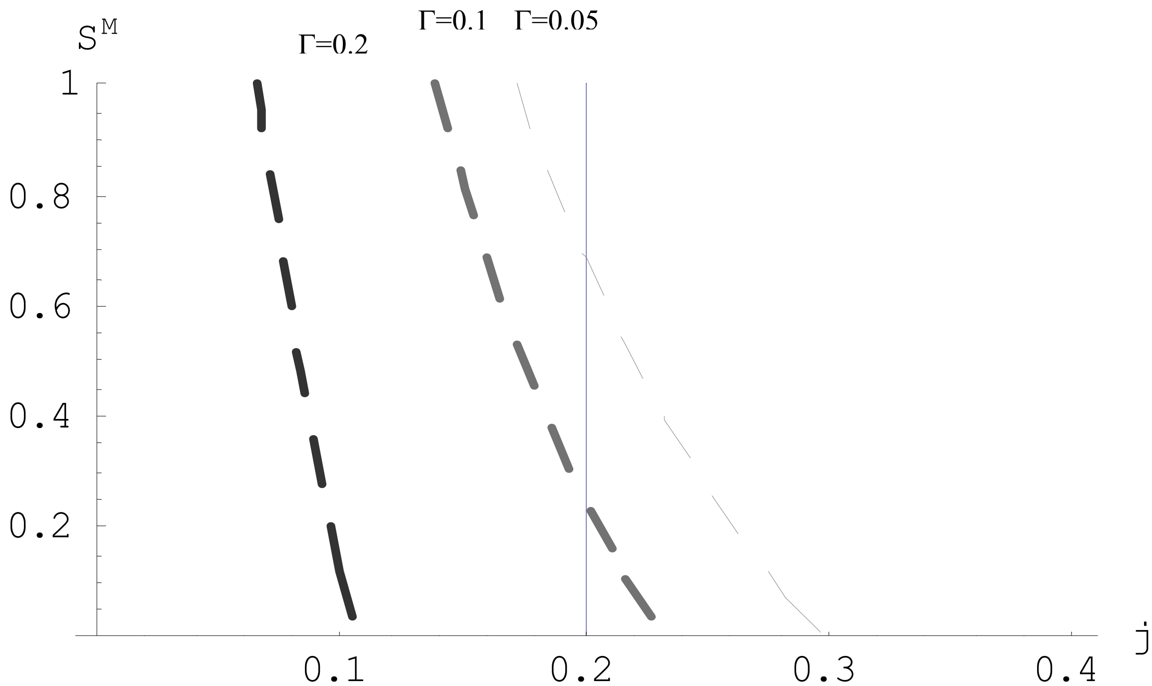


Figure 6 Effects of change in disadvantage costs on long-run growth rate

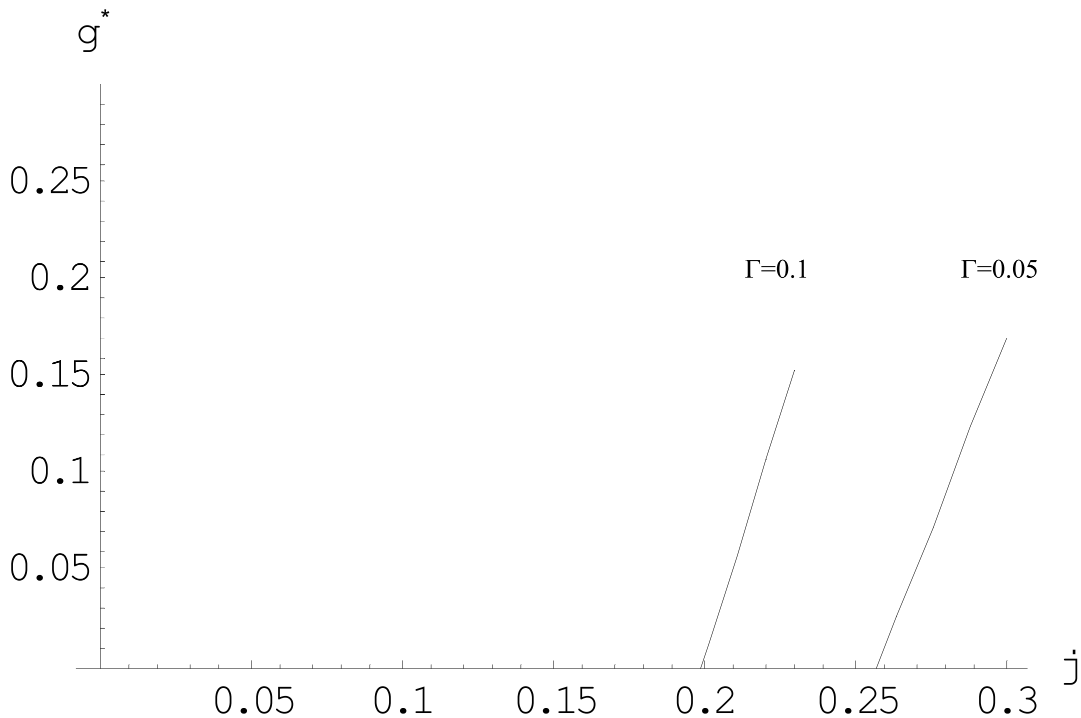


Figure 7 Effects of change in wage gap on rate of multinationalization

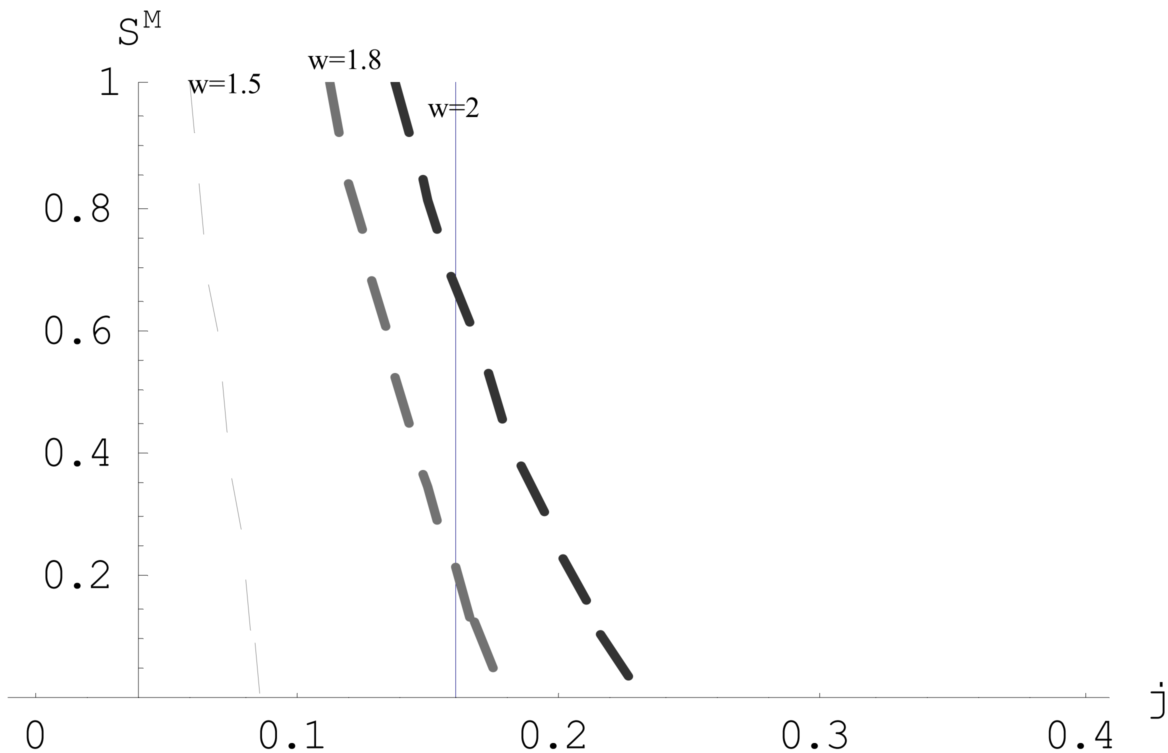


Figure 8 Effects of change in wage gap on long-run capital growth rate

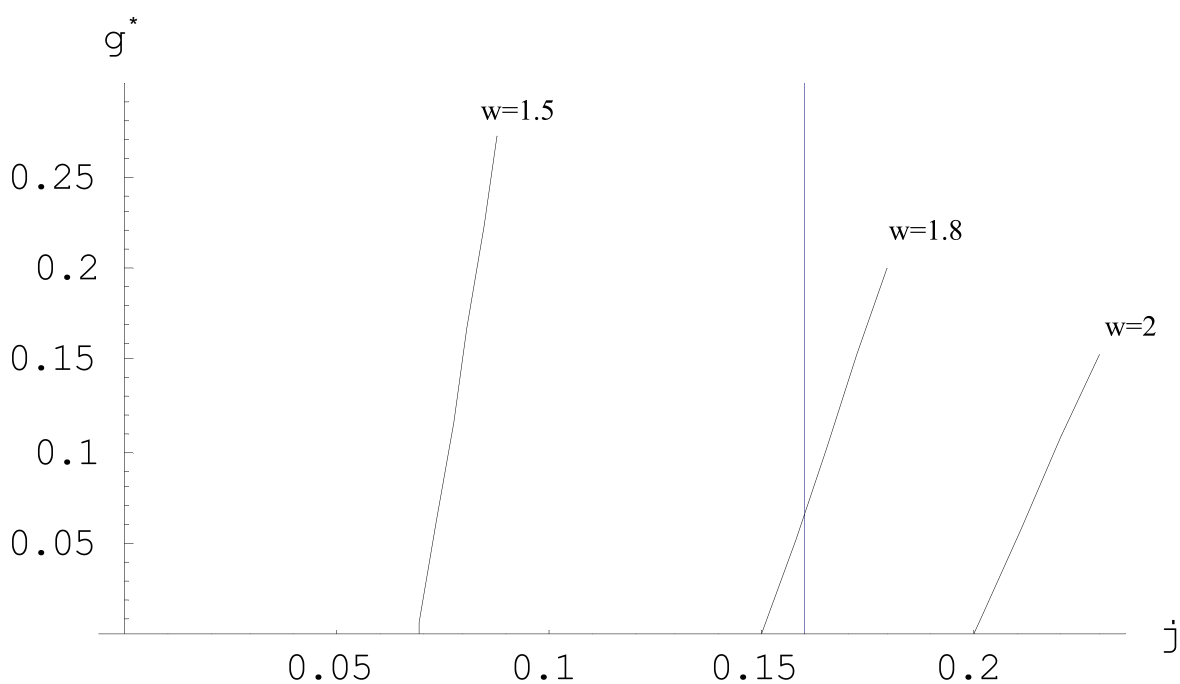


Figure 9 Effects of change in ε on rate of multinationalization

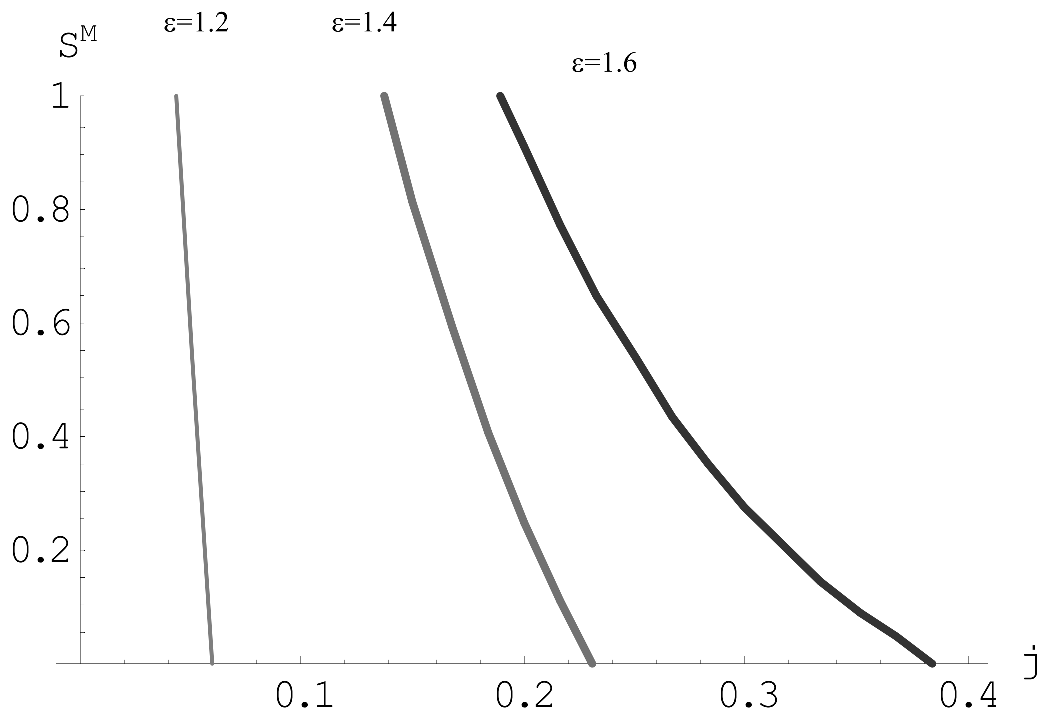
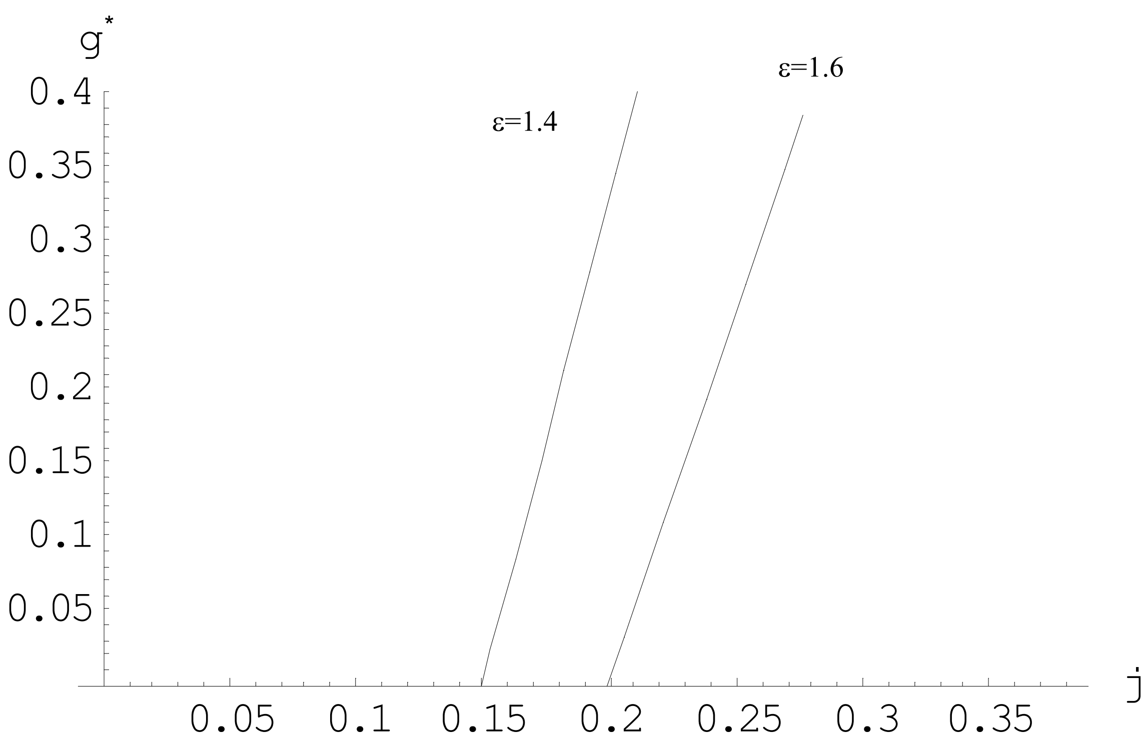


Figure 10 Effects of change in elasticity of substitution on long-run growth rate



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